What is claimed is:

Claims

1. A method comprising the steps of:

receiving a single orthogonal frequency division multiplexed (OFDM) symbol that exhibits $1/N$ symbol symmetry, where N is an integer greater than or equal to 2;

determining timing synchronization from the single OFDM symbol by applying a correlation metric to the single OFDM symbol.

2. The method of claim 1, further comprising the step of determining a fractional subcarrier frequency offset from the single OFDM symbol.

3. The method of claim 2, further comprising the step of removing the fractional subcarrier frequency offset from the single OFDM symbol.

4. The method of claim 1, further comprising the step of determining an integer subcarrier frequency offset from the single OFDM symbol.

5. The method of claim 4, wherein the step of determining the integer subcarrier frequency offset comprises the step of applying differential correlation to a frequency-shifted version of the single OFDM symbol.

6. The method of claim 4, further comprising the step of performing a fourier transform on the single OFDM prior to determining the integer subcarrier frequency offset.

7. The method of claim 1, further comprising the step of determining a subcarrier rotation from the single OFDM symbol.

8. The method of claim 7, wherein the step of determining the subcarrier rotation comprises the step of determining an angle for a maximum differential correlation of a frequency-shifted version of the single OFDM symbol.

9. The method of claim 1, further comprising the step of utilizing at least the timing synchronization to provide synchronized output symbols in subsequently received bauds.

10. The method of claim 1, wherein the step of determining comprises the step of utilizing the correlation metric to update a previously determined timing synchronization.

11. The method of claim 1, wherein the single OFDM symbol is an OFDM sync baud.

12. The method of claim 1, wherein the single OFDM symbol comprises at least one data symbol.

13. The method of claim 1, wherein *N* is an integer greater than or equal to 3.

14. The method of claim 1, wherein the method is performed by a wireless receiver.

15. A method comprising the steps of:

receiving a single orthogonal frequency division multiplexed (OFDM) symbol;

determining timing synchronization from the OFDM symbol;

determining a fractional subcarrier frequency offset from the single OFDM symbol;

removing the fractional subcarrier frequency offset from the single OFDM symbol;

determining an integer subcarrier frequency offset from the single OFDM symbol.

16. The method of claim 15, wherein the step of determining the integer subcarrier frequency offset comprises the step of applying differential correlation to a frequency-shifted version of the single OFDM symbol.

17. The method of claim 15, further comprising the step of determining a subcarrier rotation from the single OFDM symbol.

18. The method of claim 17, wherein the step of determining the subcarrier rotation comprises the step of determining an angle for a maximum differential correlation of a frequency-shifted version of the single OFDM symbol.

19. The method of claim 15, further comprising the step of utilizing at least one of the timing synchronization, the fractional subcarrier frequency offset, and the integer subcarrier frequency offset to provide synchronized output symbols in subsequently received bauds.

20. The method of claim 15, further comprising the step of utilizing at least one of the timing synchronization, the fractional subcarrier frequency offset, and the integer subcarrier frequency offset to update previously determined synchronization information.

21. The method of claim 15, wherein the single OFDM symbol exhibits $1/N$ symbol symmetry, where N is an integer greater than or equal to 2.

22. The method of claim 15, further comprising the step of performing a fourier transform on the single OFDM prior to determining the integer subcarrier frequency offset.

23. The method of claim 15, wherein the single OFDM symbol is an OFDM sync baud.

24. The method of claim 15, wherein the method is performed by a wireless receiver.

25. An apparatus comprising:

a timing synchronizer, arranged and constructed to obtain timing synchronization on a single orthogonal frequency division multiplexed (OFDM) symbol;

a fractional subcarrier frequency synchronizer, operably coupled to the timing synchronizer, wherein the fractional subcarrier frequency synchronizer is arranged and constructed to obtain fractional subcarrier frequency synchronization on the single OFDM symbol.

26. The apparatus of claim 25, wherein the fractional subcarrier frequency synchronizer is further arranged and constructed to remove a fractional subcarrier frequency offset from the single OFDM symbol.

27. The apparatus of claim 25, further comprising an integer subcarrier frequency synchronizer, operably coupled to the fractional subcarrier frequency synchronizer, wherein the integer subcarrier frequency synchronizer is arranged and constructed to obtain integer subcarrier frequency synchronization on the single OFDM symbol.

28. The apparatus of claim 25, wherein the integer subcarrier frequency synchronizer is arranged and constructed to apply a differential correlation to a frequency-shifted version of the single OFDM symbol.

29. The apparatus of claim 25, further comprising a subcarrier rotation synchronizer, operably coupled to the integer subcarrier frequency synchronizer and the timing synchronizer, wherein subcarrier rotation is arranged and constructed to obtain subcarrier rotation synchronization on the single OFDM symbol.

30. The apparatus of claim 25, wherein the subcarrier rotation synchronizer is further arranged and constructed to determine an angle for a maximum differential correlation of a frequency-shifted version of the single OFDM symbol.

31. The apparatus of claim 25, further comprising a fourier transformer that converts the single OFDM symbol to a frequency domain signal.

32. The apparatus of claim 25, wherein the single OFDM symbol is an OFDM sync baud.

33. The apparatus of claim 25, wherein the apparatus is disposed in a wireless receiver.

34. A method comprising the steps of:

receiving a single orthogonal frequency division multiplexed (OFDM) symbol;

determining an integer subcarrier frequency offset from the single OFDM symbol by applying a differential correlation metric to the OFDM symbol.

35. The method of claim 34, further comprising the step of removing a fractional subcarrier frequency offset from the single OFDM symbol prior to the determining step.

36. The method of claim 34, wherein the step of determining the integer subcarrier frequency offset comprises the step of applying the differential correlation metric to a frequency-shifted version of the single OFDM symbol and a known OFDM sync baud.

37. The method of claim 34, wherein the integer subcarrier frequency offset is found at a subcarrier shift resulting in a maximum for the differential correlation metric.

38. The method of claim 34, further comprising the step of determining subcarrier rotation by determining an angle of a maximum for the differential correlation metric.

39. The method of claim 34, wherein the differential correlation metric comprises applying the equation

$$R(s) = \sum_{k=0}^{L-3} \left[x^*(k) y((k+s) \bmod L)\right]^* \cdot \left[x^*(k+2) y((k+2+s) \bmod L)\right],$$

where $y(k)$ denotes complex received symbols, $x(k)$ denotes known symbols, L is a Fourier transform size, s is an instantaneous subcarrier shift being considered, and k is a subcarrier index.

40. The method of claim 34, wherein the integer subcarrier frequency offset, γ_2, is computed using the following formula

$$\gamma_2 = \Delta f \cdot s_{rem} \text{ where } s_{rem} = \underset{s}{\arg\max} |R(s)|,$$

where Δf is subcarrier spacing and $|R(s)|$ is the magnitude of the differential correlation metric.

41. A method comprising the steps of:

receiving a single orthogonal frequency division multiplexed (OFDM) symbol that exhibits 1/*N* symbol symmetry, where *N* is an integer greater than or equal to 2;

determining a subcarrier rotation from the single OFDM symbol.

42. The method of claim 41, further comprising the step of determining timing synchronization from the single OFDM symbol by applying a correlation metric to the single OFDM symbol.

43. The method of claim 41, further comprising the step of determining a fractional subcarrier frequency offset from the single OFDM symbol.

44. The method of claim 41, further comprising the step of determining an integer subcarrier frequency offset from the single OFDM symbol.

45. The method of claim 41, further comprising the step of utilizing at least the subcarrier rotation to provide synchronized output symbols in subsequently received bauds.

46. The method of claim 41, further comprising the step of utilizing at least the subcarrier rotation to update previously determined synchronization information.

47. The method of claim 41, wherein the single OFDM symbol is an OFDM sync baud.

48. The method of claim 41, wherein the method is performed by a wireless receiver.